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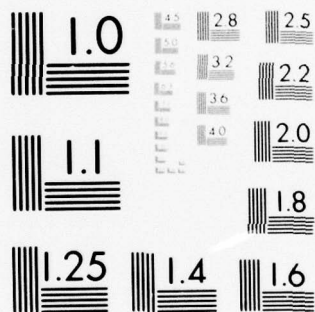
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PREFACE

The work reported on in this document was performed at the Air Force Weapons Laboratory, Kirtland AFB, NM, and was completed in October 1975.

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LIST OF SYMBOLS

Symbol	Definition
dB	Decibel
Ft	Feet
Hr	Hours
Hz	Hertz (cycles/second)
In, in	Inches
lbf	Pounds Force
MIN	Minutes
PSD	Power Spectral Density
psi	Pounds Per Square Inch
P_{rms}	Root Mean Squared of Static Pressure Fluctuation
q	Dynamic Pressure
RMS	Root Mean Squared
$^{\circ}R$	Degrees Rankine
SEC	Seconds
SQ	Squared

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INTRODUCTION

Background

Airworthiness/Flight Certification of the Airborne Laser Laboratory (ALL) aircraft in the forward ramp/partial aft fairing configuration ended in May 1974 (Refs 1 & 2). This series of tests was conducted with the dummy Airborne Pointing and Tracking System (APT) installed. In October 1974, the partial aft fairing was modified to accommodate the actual APT. This modification required the partial aft fairing to be cut away to insure APT eyelid cover clearance when the APT rotated in azimuth. On a subsequent flight the test crew noticed a low frequency buffeting of the turret and aircraft structure.

With pressure and acceleration sensors installed, the aircraft was flown on a short, low altitude test to investigate this phenomenon (Flight 50). Analysis of data gathered on this flight confirmed the existence of low frequency pressure and acceleration peaks (Ref 3). Since Flight 50 used the dummy APT, the increased buffet seemed to come from the fairing modification and not from the change in APT configuration. In an effort to reduce the effect of the fairing cutout, a brush seal was installed over the cutout area to prevent flow through the cutout region of the partial aft fairing (see Figure 1). This seal was evaluated in a following flight test with the dummy APT (Flight 52). The buffeting occurred again (Ref 4). Data from the two flights showed that the pressure fluctuations on the turret remained nearly the same; however, on the fairing and fuselage, the overall unsteady pressures decreased with the brush seal in place. Motion pictures taken during Flight 52 showed that the brush seal only partially reduced the flow between the turret and aft fairing.

Since the brush seal appeared to relieve the problem on the fairing, a more positive seal might lower the unsteady pressures. To determine whether a more positive seal would be more effective (without creating a detailed design for such a seal), the right side of the fairing was sealed with a rubber seal and RTV cement. The ALL Buffet Committee agreed that

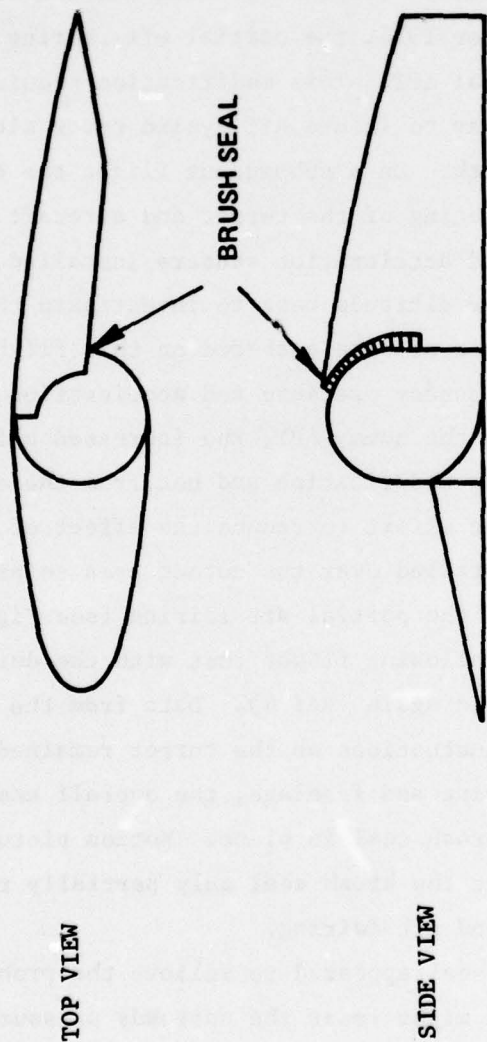


FIGURE 1. Installation of Brush Seal, Flight 52.

if the positive seal failed to give the desired results, redesign of the apt fairing would be necessary (Ref 4). This report summarizes the results of the final flight test, Flight 74.

Objective

The objective of Flight 74 was to determine the effectiveness of completely sealing the gap between the APT and the partial aft fairing. It was never intended to result in a permanent fix, but was to evaluate the potential of the partial aft fairing.

Method of Test

The dummy APT, forward ramp, and partial aft fairings were installed on the ALL aircraft for this flight test. The gap on the right side between the fairing and the turret was sealed with a rubber seal and RTV cement (as Figure 2 shows). Due to the high overall unsteady pressure levels and their unusual frequencies, Flight 74 terminated early. Data was recorded at only one of the pre-planned test points. However, data was also recorded when the aircraft was in a steady condition while enroute to final approach for landing. These two data samples are the only data gathered on this flight. Table 1 lists these test points.

TABLE 1. FLIGHT TEST DATA POINTS, FLIGHT 74

TIME (HR:MIN:SEC)	MACH	PRESSURE ALTITUDE (FT)	RAM AIR TEMPERATURE (°R)	VELOCITY (Ft/Sec)	q (lbf /in ²)
18:49:50	Preflight Noise				
19:43:20	0.42	12,590	507	460	1.15
20:17:15	0.35	7,000	532	386	0.95
20:54:40	Post Flight Noise				

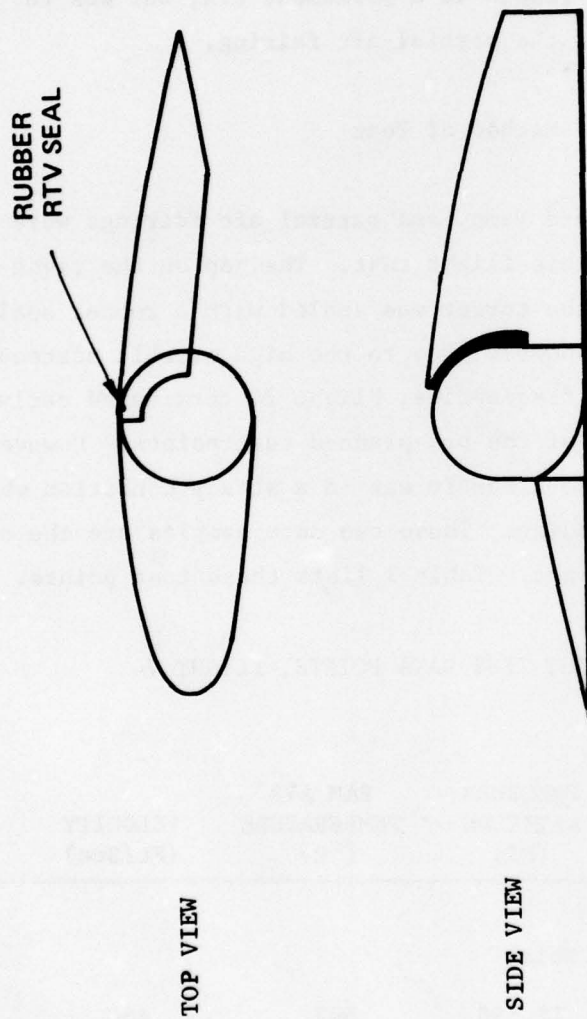


FIGURE 2. Installation of Rubber RTV Seal, Flight 74.

Kulite Model XQCL-093-123-25 high response pressure transducers were located on the turret, fairing, and aircraft fuselage (as Figure 3 shows). Two triads of Kulite, model 625 piezoresistive accelerometers were located in the turret and fairing (Figure 3).

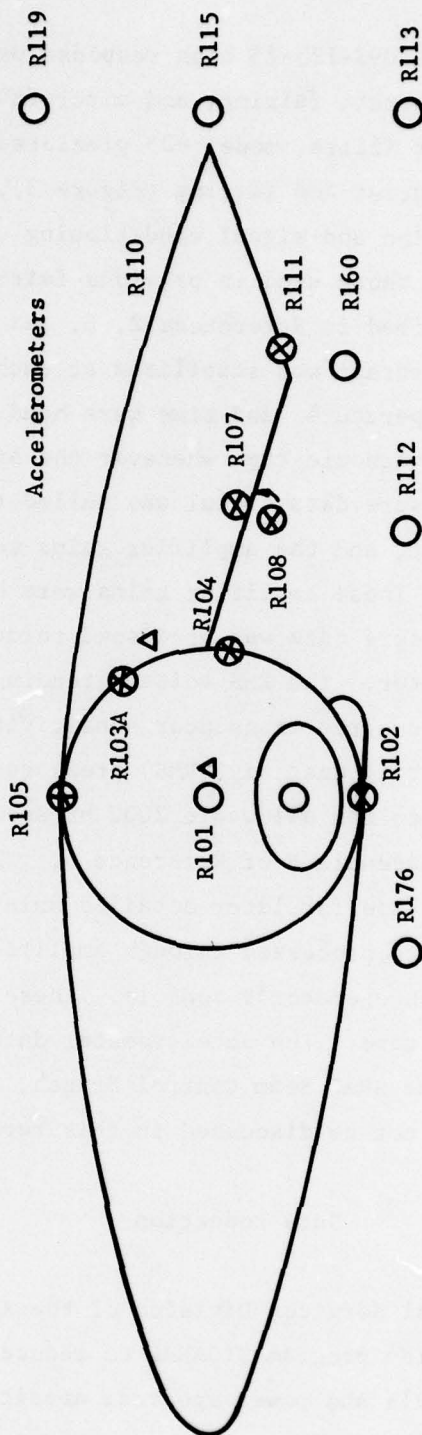
The instrumentation and signal conditioning used in this flight test were the same as those used in previous fairing flight certification flights and are described in References 2, 5, and 6.

When the test aircraft was stabilized at each data point, airspeed, altitude, ram air temperature, and time were hand recorded. This data was also recorded on magnetic tape whenever the aircraft recorders were turned on. Each pressure data signal was nulled to minimize the steady state signal component, and the amplifier gains were adjusted to maximize the unsteady signal. These amplifier gains were hand recorded on the data sheet. The pressure data was processed through a Hewlett-Packard 3400A True RMS voltmeter. The RMS voltage readings were recorded and converted using the required transducer sensitivity gain and conversion factor to overall unsteady (RMS) pressures. These pressure levels were compared to the allowable 2000 hr acoustic fatigue lifetime limits discussed in Appendix B of Reference 6. The data were then recorded on magnetic tape for later detailed analysis. The outputs of the accelerometers were processed through amplifiers and were monitored at the instrumentation operator's console. These data were recorded directly on magnetic tape. The accelerometer data have been reduced and are available from the SRAT Beam Control Branch, Air Force Weapons Laboratory, but will not be discussed in this report.

Data Reduction

The Computational Services Division of the Air Force Weapons Laboratory used the Data Reduction program SIGANAL to reduce the pressure data to overall unsteady levels and power spectral densities. Ten seconds of pressure data were digitized at a rate of 2000 samples per second. The data was filtered at 1000 Hz during the recording and digitizing process. Overall root mean squared levels were computed by calculating the standard

TRANSDUCER	R101	R102	R103A	R104	R105	R106	R107	R108
STATION	490.0						551.6	551.6
BUTTLINE							0	
WATERLINE	362.0	335.0	335.0	335.0	335.0	351.35		334.0L
AZIMUTH		90°	230°	185°	270°	90°		



TRANSDUCER	R110	R111	R112	R113	R115	R119	R160	R176
STATION	613.2	613.2	551.6	677.8	677.8	677.8	610.0	428.8
BUTTLINE						2.4R		
WATERLINE	317.6R	317.6L	289.5L	289.5L	289.5R	295.3L		289.5L

FIGURE 3. Fairing and Fuselage Instrumentation Locations, Flight 74

deviation of the data about the mean for 8.19 seconds. As a check, the overall levels were also calculated by integrating the power spectra and taking the square root. The power spectral densities (PSD) were computed using 16,384 raw data points. The sample time for this calculation was 8.19 seconds. Smoothed PSDs were plotted using the bandwidths listed in Table 2.

TABLE 2. BANDWIDTHS FOR PRESSURE PSDs FROM FLIGHT TEST WITH SEALED PARTIAL AFT FAIRING

Frequency Range (Hz)	Bandwidth (Hz)
0-20	1
20-100	5
100-500	10
500-1000	20

The confidence limits were determined using the method outlined in Reference 7.

TABLE 3. 95 PERCENT CONFIDENCE LIMITS FOR PRESSURE DATA FROM FLIGHT TEST WITH SEALED PARTIAL AFT FAIRING

Frequency Range (Hz)	Upper Limit Percent PSD Function	Lower Limit Percent PSD Function
0.98-20.51	231.5	55.5
23.49-103.57	140.4	79.0
111.08-501.46	126.2	84.3
516.48-976.93	117.8	88.5
Nyquist Frequency 1000HZ		

Table 3 shows the limits at the 95 percent confidence level. Instrumentation noise levels were recorded with the engines running before and after the test flight. Figure 4 is typical of the levels and spectra recorded.

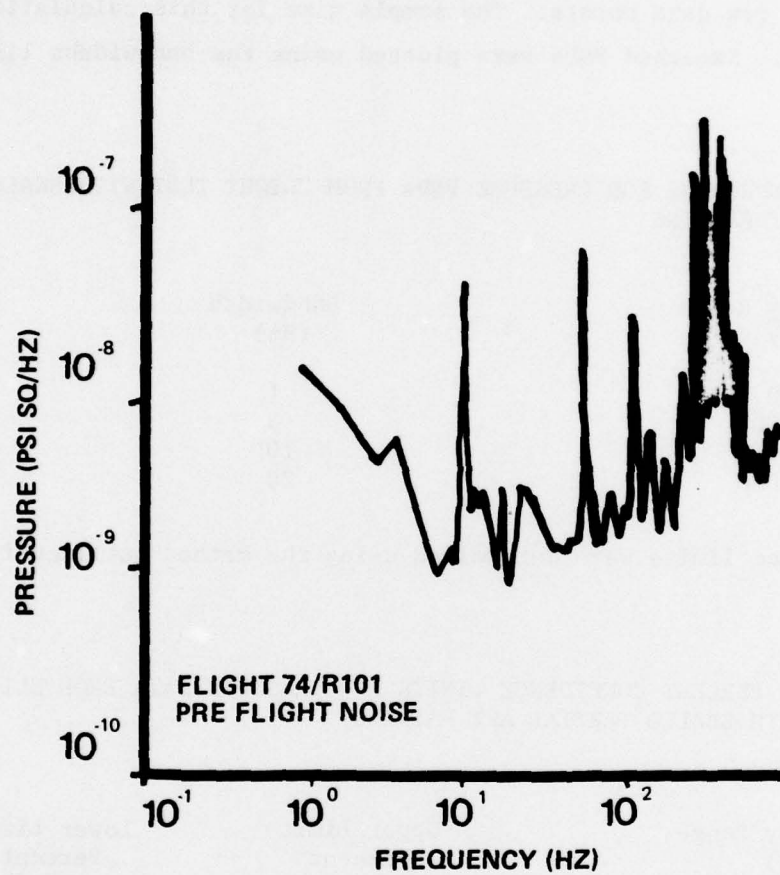


FIGURE 4. Typical Pressure Instrumentation Noise Level

RESULTS

The pressure data are presented as overall unsteady (RMS) levels and as power spectral densities (PSD). Table 4 lists the overall unsteady pressure levels found on the turret, fairing, and aircraft fuselage. The relative unsteady pressure levels recorded are much higher than previously experienced anywhere in the flight envelope. The highest unsteady pressure value ($P_{rms}/q_{\infty} = 0.2126$), when scaled to the maximum dynamic pressure in the ALL flight envelope (2.91 psi), gives an overall unsteady pressure level of 166.6 dB based upon 2.9×10^{-9} psi or 2.4×10^{-4} dynes/cm². This level is above the maximum allowable level of 164 dB (Ref 6). This method of scaling does not include any factor for Mach number effects. Previous airborne and wind tunnel measurements have noted a rise in the relative size of the unsteady fluctuation (P_{rms}/q) at lower Mach numbers (around Mach .5) (Ref 6). The magnitudes noted during this test were much larger than anticipated or previously observed (Refs 1, 2, 5). This in itself was cause for considerable concern.

Table 5 contains data from Flight 50 (cutout without seal) and Flight 52 (cutout with brush) that were taken at similar Mach numbers. Unfortunately, no data was taken at low Mach numbers prior to the cutout modification. The lowest Mach number from Flight 42 is Mach 0.5. This data is presented only to show that the relative levels recorded prior to the modification were much lower than those recorded on later flights. Comparison of the data from the three flights shows very little difference in the overall unsteady pressure levels on the turret. Addition of the brush seal appears to reduce the levels on fairing and fuselage (R 106-R 176) but does nothing to help the turret environment (R 101-R 104). Complete sealing of the gap has little effect on the overall levels (compared to the brush seal).

Examination of the power spectra at the two test points reveals a dominant peak at a frequency of 4 Hz. Figures 5 and 6 are typical PSDs for the pressure variations on the turret and in the cutout region. This low frequency peak was also picked up downstream on the fuselage at R 160 and R 113. Curiously, it is not evident at R 112 or R 111. A complete

TABLE 4. OVERALL UNSTEADY PRESSURE LEVELS - FLIGHT 74

TRANSDUCER	18:49:50 PREFLIGHT NOISE Prms (dB)	19:43:20 ALT 12,590 FT MACH .42 $q = 1.15$ psi Prms/q	20:17:15 ALT 7000 FT MACH .35 $q = .95$ psi Prms/q	20:54:40 POST FLIGHT NOISE Prms (dB)
R101	123.8	.1650	.0988	118.7
R102	126.3	.0703	.0777	118.7
R103A	129.7	.0907	.0919	124.1
R104	130.7	.1357	.1286	123.7
R105	-	-	-	-
R106	131.1	.0492	.0511	123.4
R107	125.8	.1390	.0887	124.5
R108	130.4	.2126	.1743	-
R109	-	-	-	-
R110	-	-	-	-
R111	132.4	.0503	.0435	125.3
R112	130.1	.1464	.1428	122.9
R113	131.3	.0613	.0586	123.9
R115	136.3	.0238	.0234	128.2
R119	130.6	.0088	.0136	124.3
R160	132.2	.1142	.1144	124.4
R176	-	-	-	-

1. *The decibel (dB) level is referenced to 2×10^{-4} DYNES/cm² or 2.9×10^{-9} psi
 2. A dash indicates that either the data was unusable or unavailable

TABLE 5. COMPARISON OF FLIGHT TEST DATA

Transducer	Flight 50 (No Seal) MACH .402 q=1.14 psi Prms/q	Flight 52 (Brush Seal) MACH .355 q=.86 psi Prms/q	Flight 74 (Rubber Seal) MACH .35 q=.95 psi Prms/q	Flight 50 (No Seal) MACH .42 q=1.24 Prms/q	Flight 74 (Rubber Seal) MACH .42 q=1.15 psi Prms/q	Flight 42 (No Cutout) MACH .495 q=1.54 Prms/q
R101	.1172	.1400	.0988	.1406	.1650	-
R102	.0543	-	.0777	.0998	.0703	-
R103A	.0644	.0473	.0919	.1327	.0907	-
R104	.1796	.1377	.1286	.2156	.1357	-
R105	.0348	.0201	-	.1567	-	-
R106	.0424	.0499	.0511	.0419	.0492	-
R107	.2105	.0941	.0887	.2131	.1390	-
R108	.3043	.1956	.1743	.3181	.2126	-
R109	.2520	-	-	.2350	-	.078
R110	.0146	.0166	-	.0229	-	-
R111	.0925	.0444	.0435	.0786	.0503	-
R112	.2275	.1460	.1428	.2127	.1464	.086
R113	-	.0644	.0586	-	.0613	.033
R115	.0698	.0250	.0234	.0339	.0238	.023
R119	.0142	.0165	.0136	.0173	.0088	-
R160	.2131	.1144	.1144	.1770	.1142	.069
R176	-	-	-	-	-	-

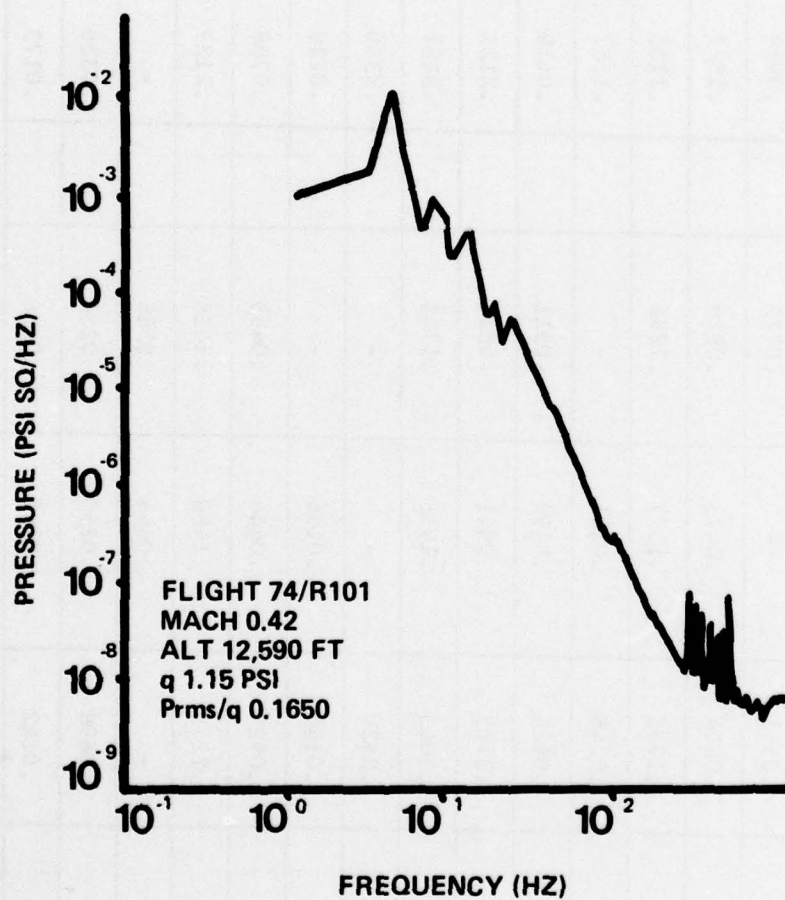


FIGURE 5. Typical Turret Pressure Power Spectra, Flight 74, Mach 0.42

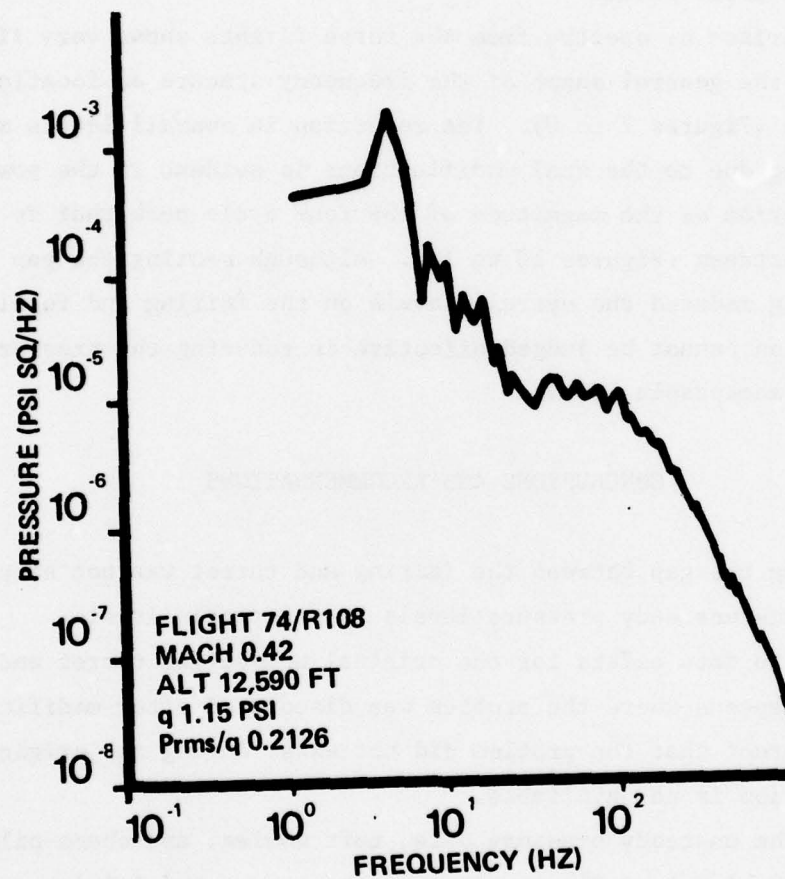


FIGURE 6. Typical Fairing Pressure Power
 Spectra, Flight 74, Mach 0.42

set of pressure power spectra appear in the Appendix. The low frequency peak corresponds to observations by the photo-chase aircraft pilot, who noted a vortex shed from the turret at approximately four cycles per second. From its origin near the top of the fairing, the shed vortex moves to the rear and nearly covers the entire side of the fairing at the cutout break point.

Comparison of spectra from the three flights shows very little difference in the general shape of the frequency spectra at locations on the turret (Figures 7 to 9). The reduction in overall levels measured on the fairing due to the seal modifications is evident in the power spectra as a reduction of the magnitude of the four cycle peak that is propagated downstream (Figures 10 to 12). Although sealing the gap between the fairing reduced the overall levels on the fairing and fuselage, the modification cannot be judged effective in reducing the pressure variations to acceptable levels.

CONCLUSIONS AND RECOMMENDATIONS

1. Sealing the gap between the fairing and turret was not effective in reducing the unsteady pressure levels to acceptable levels.
2. Since no data exists for the original unmodified turret and fairing at the airspeeds where the problem was discovered after modification, positive proof that the problem did not exist during the original flight certification is not available.
3. From the unsteady pressure data, tuft movies, and chase-pilot observation, the high load fluctuations on the turret and fairing appear to be caused by a vortex that is shed from the top of the fairing along the cutaway portion of the partial aft fairing. This vortex shedding causes a low frequency beating on the turret and fairing as the flow alternately separates and reattaches.
4. Due to design restrictions that do not permit devices to fix the separation point on the movable turret, redesign of the aft fairing is necessary to eliminate the separation problem.

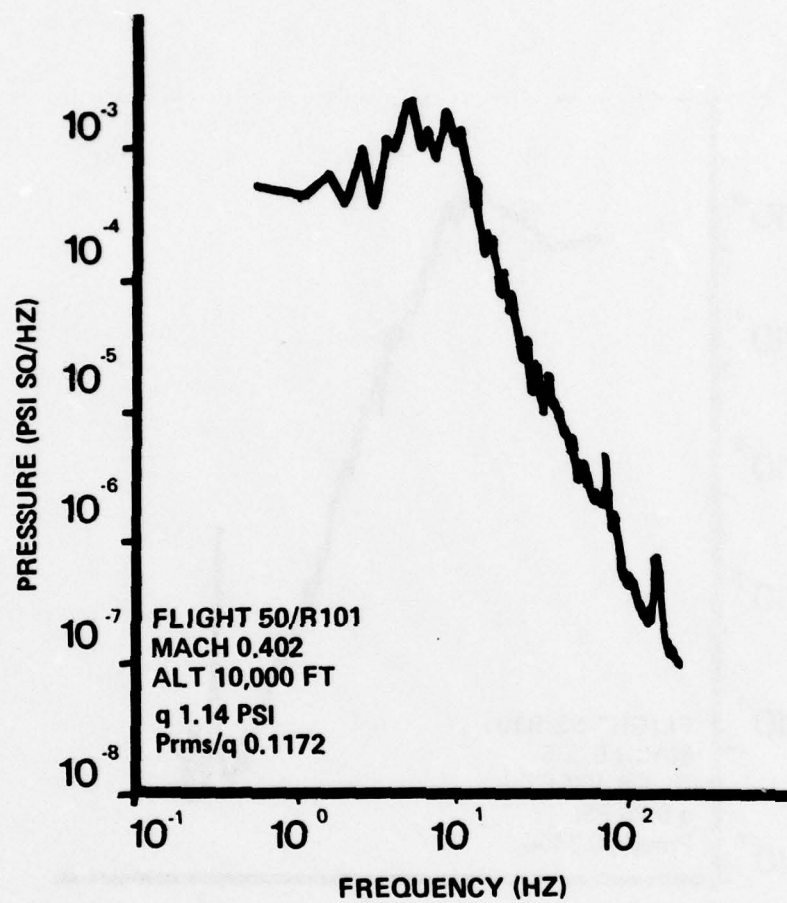


FIGURE 7. Typical Turret Pressure Power Spectra, Flight 50, Mach 0.402

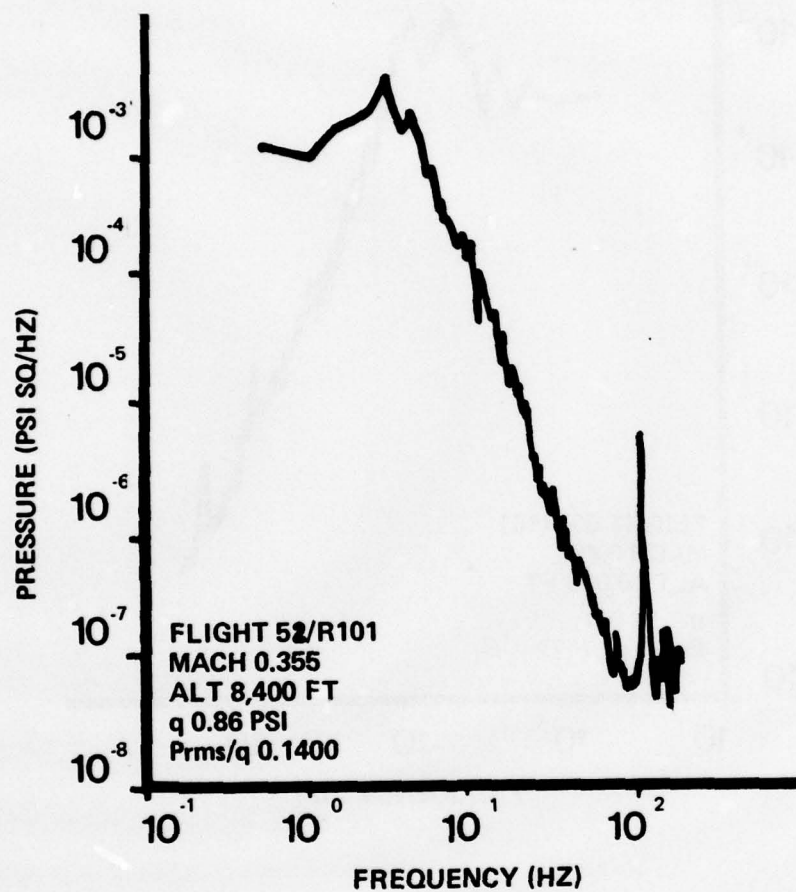


FIGURE 8. Typical Turret Pressure Power Spectra, Flight 52, Mach 0.355

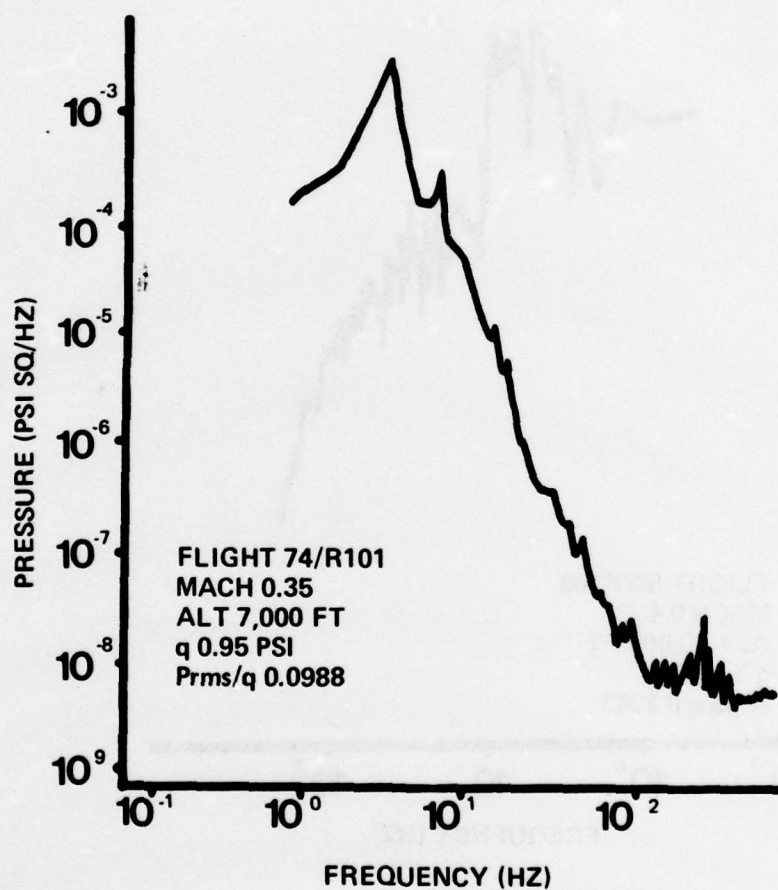


FIGURE 9. Typical Turret Pressure Power Spectra, Flight 74, Mach 0.35

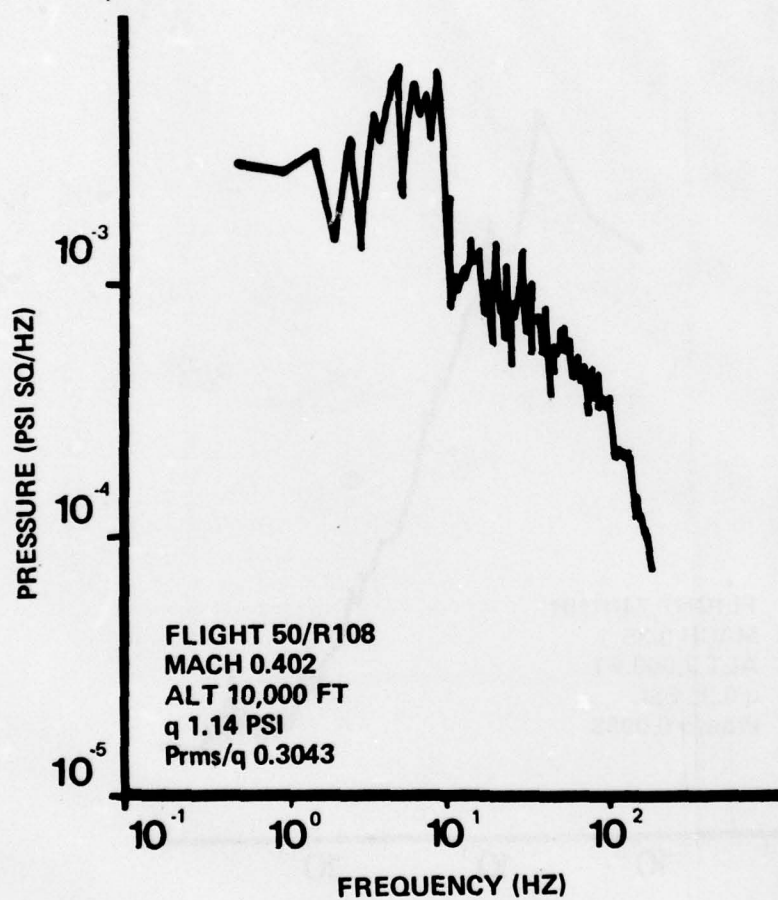


FIGURE 10. Typical Fairing Pressure Power Spectra, Flight 50, Mach 0.402

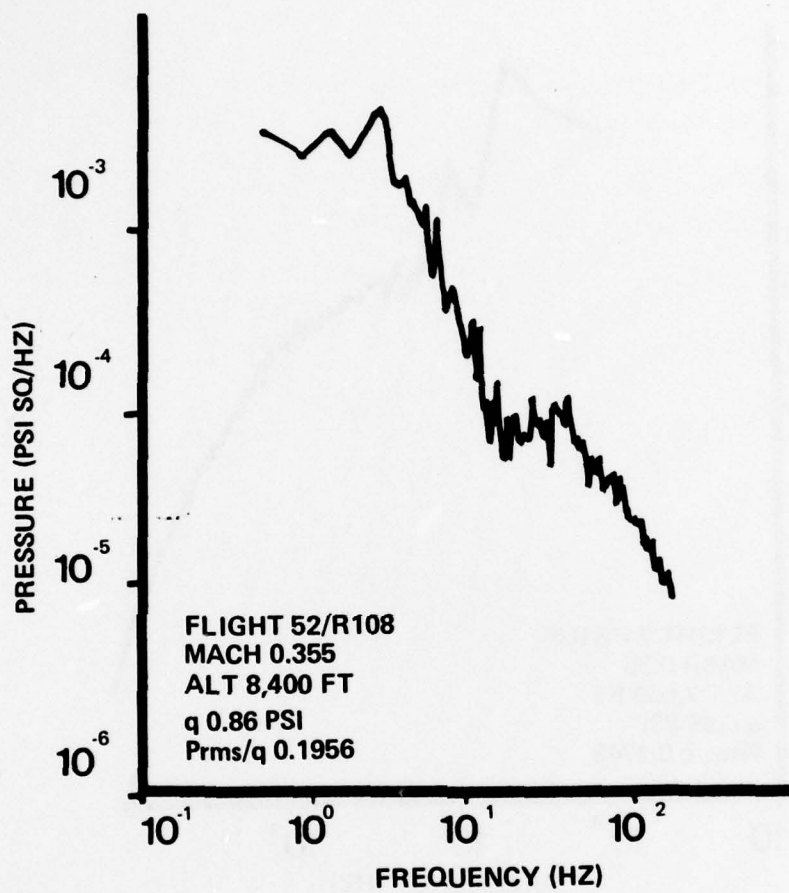


FIGURE 11. Typical Fairing Pressure Power Spectra, Flight 52, Mach 0.355

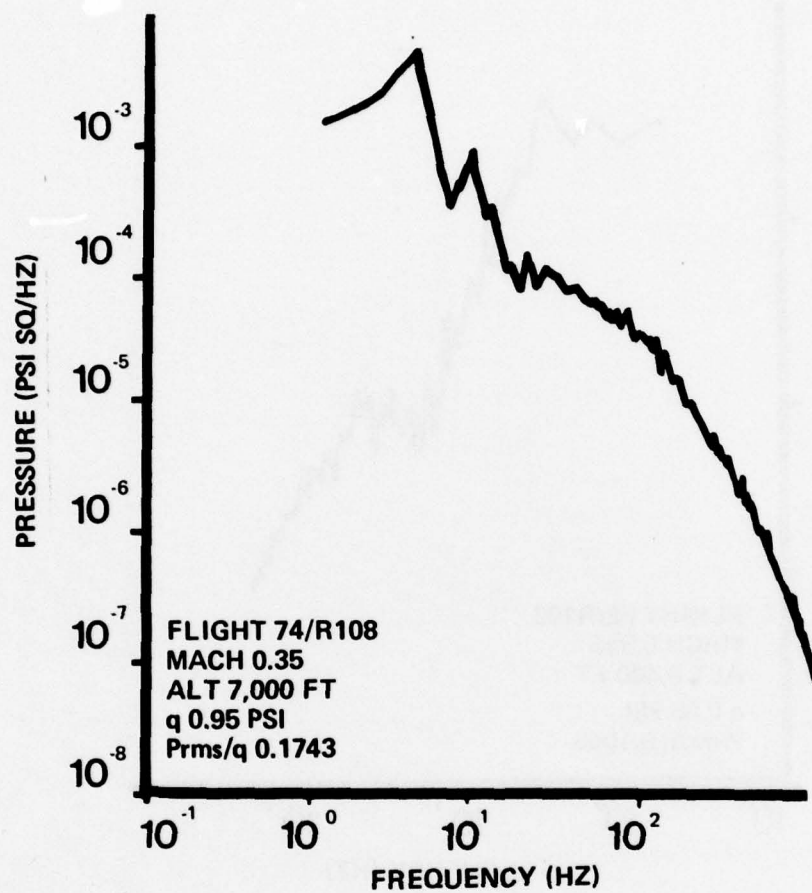


FIGURE 12. Typical Fairing Power Spectra,
Flight 74, Mach 0.35

LIST OF REFERENCES

1. Crane, J. C. Airworthiness Report, ALL Cycle II. AFSWC/FTEM, September 1974.
2. Davis, J. A. Airborne Laser Laboratory NKC 135A Flight Test Pressure Data for the Forward Ramp. AFWL TR-75-82, Air Force Weapons Laboratory, November 1975.
3. Davis, J. A. ALL Buffet Problems/October 1974. AFWL Memorandum, Air Force Weapons Laboratory, 31 October 1974.
4. Icardi, S. E. Report of ALL Buffet Committee, 5 Dec 74. AFWL Memorandum, Air Force Weapons Laboratory, 23 December 1974.
5. Otten, L. J. Measurement and Analysis of External Unsteady Pressures on the Airborne Laser Laboratory. AFWL TR-73-141, Air Force Weapons Laboratory, August 1973.
6. Icardi, S. E. Pressure Measurements from Airborne Laser Laboratory Open Port Flight Tests. AFWL TR-76-170, Air Force Weapons Laboratory, March 1976.
7. Otnes, R. K. et. al. Digital Time Series Analysis. New York: Wiley & Sons, 1972.

APPENDIX
UNSTEADY PRESSURE DATA, FLIGHT 74

This appendix contains a complete set of pressure data from Flight 74. Each figure is identified with flight number, transducer location, Mach number, pressure altitude, dynamic pressure, and overall unsteady pressure reading non-dimensionalized with dynamic pressure.

